Section 3 Energy-Dispersive X-ray Fluorescence (EDXRF) Analysis

3.1 Introduction to EDXRF Analysis

The use of Energy-Dispersive X-ray Fluorescence (EDXRF) may make it possible to determine if lithic artifacts of the project area are from similar or different sources or from distant sources (such as, for example, from another island). Using a EDXRF spectrometer, Dr. Peter Mills of the University of Hawaiʻi at Hilo is working to establish geochemical "fingerprints" of stone tools that traditional Hawaiians quarried from various sites and to track the extent to which that material was circulated on an island or throughout the islands. The EDXRF analyzer allows archaeologists to conduct rapid and non-destructive analyses of stone artifacts to determine the extent and distance to which stone tools moved from the quarries. Attempts were made to match the lithic artifacts found with geochemical data collected on known prehistoric quarry areas. Samples that do not match known quarry sites may lead to the discovery of currently unknown quarry sites, or possibly to the identification of stone tools derived from other island groups such as Tahiti and the Marquesas. By examining the extent to which stone tools in various *ahupuaʻa* were derived from non-local sources, archaeologists will be able to quantify traditional Hawaiian movement of lithic artifacts through time and space and possibly identify some tools that were carried over long distances of open ocean. Although EDXRF analysis shows great promise, the data base of analyzed samples is still small (and somewhat geographically skewed in favor of the Big Island at present).

It should be noted that the entire lithic assemblage recovered in the course of the HHCTCP City Center Section AIS (Table 4) was very modest and did not include any lithic tools (other than volcanic glass) or any polished flakes. Thirty samples were sent for EDXRF analysis including 28 samples of volcanic glass, an *ʻulu maika*, and a basalt waste flake (see Table 4 and Table 3.

3.2 Results of EDXRF Analysis

The results of EDXRF analysis are presented in detail in Table 3 and are summarized in Table 4. The analysis of the volcanic glass suggests that there were two different geological sources. Dr. Mills explains.

> There are two geochemical groups of volcanic glass. We are still working out the range of local volcanic glass for Oʻahu, but it's safe to say that neither of these groups match the VG found in Big Island sites, and our best guess at the moment is that these geochemical groups will be consistent with local Oʻahu sources. The long "comet" trails on each group on the Sr and Zr plots are due to the very small sizes of the samples (Dr. Peter Mills, personal communication, February 19 2013).

Table 3.EDXRF Data for HHCTCP City Center lithic samples

	Na2O	MgO	Al2O3	SiO2	K2O	CaO	TiO2	V	MnO	Fe	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Ba	La	Ce	Pb	Group
	%	%	%	%	%	%	%	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
S-1 vg												108.152	123.143	9.661	408.688	26.104	164.747	12.604				0.155	1
S-2 vg												185.387	113.745	5.162	271.005	15.534	109.583	9.542				0	1
S-5.1 vg												68.73	98.032	7.543	283.387	13.44	105.441	7.5				1.062	1
S-5.2 vg												89.283	81.524	4.309	242.663	13.211	76.29	7.892				0	1
S-5.3 vg												43.097	76.69	5.155	112.596	6.236	39.87	4.21				0.19	1
S-8 vg												71.634	116.779	6.39	249.135	11.151	86.632	8.879				2.173	1
S-13 vg												128.722	108.33	8.343	342.786	20.385	124.069	9.209				1.805	1
S-14 vg												113.01	144.871	10.12	351.164	21.464	143.365	5.286				0.622	1
S-18.1 vg												103.373	104.612	4.829	325.638	17.946	110.064	8.853				6.781	1
S-18.2 vg												41.259	84.377	2.981	213.119	10.453	66.656	5.83				4.042	1
S-19 VG	1.518	7.886	11.722	48.727	0.63	10.145	2.198	267.868	1625.222	7.01	90.995	129.287	129.924	9.936	409.13	23.157	147.95	15.306	174.849	6.499	22.562	1.078	1
S-19 vg.2												89.149	109.166	5.352	286.324	15.41	88.142	9.544				3.008	
S-20 vg												21.756	32.828	1.961	138.961	6.293	23.728	3.149				4.737	1
S-21.1 vg												122.307	119.973	8.881	398.634	21.305	135.421	11.223				0	1
S-21.4 vg												37.639	34.747	2.483	81.58	7.034	38.083	4.82				5.425	1
S-21.5 vg												80.889	93.847	6.434	227.124	16.7	94.717	7.249				1.986	1
S-22 vg												98.987	105.41	7.386	299.821	17.048	104.677	7.511				0	1
S-23 vg												79.587	87.856	4.384	204.003	7.209	69.025	9.636				1.143	1
S-24 vg												130.798	130.778	9.05	398.991	25.523	154.42	11.712				0	1
S-25 vg												62.83	79.36	3.572	62.495	8.337	51.589	3.149				1.308	1
S-26 vg												83.203	106.851	7.65	306.809	18.893	119.476	8.366				0	1
S-27.3 vg												94.353	97.113	4.914	303.939	17.529	106.039	11.413				0	1
S-28 vg												70.58	85.858	3.654	161.276	12.267	57.138	3.149				6.791	1
S-29.1 vg												115.424	119.238	9.652	366.08	20.254	134.369	9.598				0	1
S-29.2 vg												110.467	120.431	9.172	358.498	21.382	133.003	11.366				0	1
S-5.4 vg												19.609	184.983	30.714	453.065	49.097	381.074	34.414				2.395	2
S-6 vg												18.875	132.457	23.956	326.095	35.622	273.728	24.478				0	2
S-7 vg	1.026	7.374	14.684	54.544	1.355	5.034	3.245	297.352	1658.796	16.49	13.044	24.643	180.542	29.587	463.787	49.006	402.209	36.222	635.519	9.683	54.901	1.29	2
S-10.2 vg												18.791	110.382	16.92	271.249	28.121	223.605	19.619				0	2
S-11 vg	2.655	2.808	9.04	44.546	1.144	5.235	2.818	243.949	1692.418	7.774	10.996	19.986	160.542	29.164	432.413	44.378	368.86	33.387	601.154	19.825	49.566	0	2
S-15 vg												23.46	181.773	31.356	463.317	51.818	403.345	35.847				0	2
S-27.1 vg												27.459	187.247	31.287	485.056	52.252	414.178	35.624				0	2
S-27.2 vg												18.369	181.532	30.652	466.677	48.598	405.784	33.246				0	2
S-30 vg												18.135	136.26	25.087	351.459	38.176	304.271	26.017				0.166	2
S-16 vg												85.596	96.42	6.17	370.537	16.987	79.42	5.412				3.473	1'
S-12 FG basalt flake interior single facet	0.28	17.44	5.825	38.51	0.567	12.436	2.283	240.273	1691.395	11.04	169.689	34.004	168.536	30.005	1062.081	28.007	179.642	56.199	1390.481	56.81	172.39	0	basalt flake
S-17 ulumaika	1.433	5.378	10.985	38.988	0.382	16.321	1.666	209.959	1239.193	6.209	71.526	108.052	120.549	3.792	751.686	25.488	120.649	8.596	99.396	23.248	42.796	21.401	Ulumaika

Table 4. EDXRF Sample Summary for HHCTCP City Center lithic samples

Sample #*	**Trench**	**Stratum**	**Feature**	**Depth (cmbs)**	**Weight (g)**	**Artifact**	**Comments**
1	014	II	-	80–07	0.1	Volcanic glass	Group 1**
2	020A	II	-	236–253	0.4	Volcanic glass	Group 1
5	096	II	-	134–164	0.1	Volcanic glass	Group 1 and Group 2**
6	120	II	C	112–126	0.3	Volcanic glass	Group 2
7		II	D	110–118	1.5	Volcanic glass	Group 2
8		II	E	107–120	<0.1	Volcanic glass	Group 1
10	120A	II	-	110–118	0.4	Volcanic glass	Group 2
11		II	4	128–132	0.1	Volcanic glass	Group 2
12	120B	II	-	110–130	51.4	Basalt core debitage	-
13		II	-	130–140	0.1	Volcanic glass	Group 1
14	123	III	-	180–192	0.1	Volcanic glass	Group 1
15	124	IIa	1	118–136	0.1	Volcanic glass	Group 2
16		IIb	8	144–162	0.1	Volcanic glass	Group 2
17	142	IIa	2	44–52	180.2	*‘Ulu maika*	-
18	146A	IIa	2	75–90	0.2	Volcanic glass	Group 1
19		IIa	4	85–95	1.0	Volcanic glass	Group 1
20	150	II	3	90–130	0.1	Volcanic glass	Group 1
21	151	Id	2	53–75	0.8	Volcanic glass	Group 1
22		IIa	-	80–97	0.1	Volcanic glass	Group 1
23	151A	Id	1	57–78	0.1	Volcanic glass	Group 1
24	226A	IIa	3	97–100	0.1	Volcanic glass	Group 1
25	226B	II	-	73–76	0.1	Volcanic glass	Group 1
26		II	2	80–90	0.1	Volcanic glass	Group 1
27		II	3	82–93	1.1	Volcanic glass	Group 1 and Group 2
28		II	5	76–90	0.1	Volcanic glass	Group 1
29	227A	IIa	2	108–131	0.5	Volcanic glass	Group 1
30		IIa	4	94–108	0.2	Volcanic glass	Group 2

* certain samples were found to not be volcanic glass and have been deleted

** volcanic glass was divided into groups on the basis of Sr/Zr ratios indicating two different deological sources

A diagram of the Strontium (Sr) vs. Zirconium (Zr) ratios (Figure 24) of the HHCTCP City Center volcanic glass samples was prepared. The ratio of these two elements is understood to be particularly useful in comparing the elemental fingerprints of volcanic glass. The volcanic glass samples submitted for analysis do indeed appear to fall into two geochemical groups (Figure 24) each with very similar elemental fingerprints. Thus almost certainly the samples falling into each of the two groups came from two discrete geological sources.

As Dr. Mills notes “we are still building our O‘ahu data base” and, in the absence of extensive comparative data, the affinities of the two volcanic glass geochemical groups are not clear cut. The two geochemical sample groups from the HHCTCP City Center lithic samples were compared with the strontium to zirconium ratios for volcanic glass from Pu‘u Wa‘awa‘a on Hawai‘i Island (Figure 25) and to data from a Waiāhole O‘ahu volcanic glass source (Figure 26). The comparison to the Pu‘u Wa‘awa‘a glass was made because 1) volcanic glass from that source was very widespread, and 2) the comparison provides clarification regarding the precission of the comparative technique. It appears clear that there are minimal similarities to the widespread Pu‘u Wa‘awa‘a glass (Figure 26). Volcanic glass from the Waiāhole source, on the other hand, indicated overlap with the Group 1 volcanic glass samples (but not with the Group 2 sample cluster volcanic glass samples). All that can be said with certainty is that the geochemistry of the Group 1 samples is similar to the Waiāhole volcanic glass source but geographical proximity for the geological origin of the Group 1 samples to Waiāhole is suggested. No such geographic proximity is suggested for the Group 2 volcanic glass and we cannot otherwise speculate on the location of their geological source.

The only other lithic samples were a gaming stone and a basalt flake. Dr. Mills commented with the following:

> The [‘*ulu maika*] and basalt flake are both relatively high in Sr, which suggests they are from alkalic lavas. It is quite clear that the flake is not from the Waiahole adze quarry on the north shore of O‘ahu.
>
> They don’t closely match the samples that we have run from the H3 project or from the US Army Garrison on O‘ahu,… At this point, it is safe to say that they don’t match the Ko‘olau basalts or the early shield building phases of the Wai‘anae volcanic series. (Dr. Peter Mills, personal communication, February 19 2013)

A plot of the gaming stone and basalt flake results against the volcanic glass (Figure 27) suggests they came from different geological sources. A comparison against other samples from elsewhere in the Hawaiian Islands is shown in Figure 28. The basalt game stone bears a quite close elemental signature to a lithic sample from Nualolokai on Kaua‘i and the basalt flake shows similarities to Big Island (Pu‘u Wa‘awa‘a samples). These similarities may be coincidental.

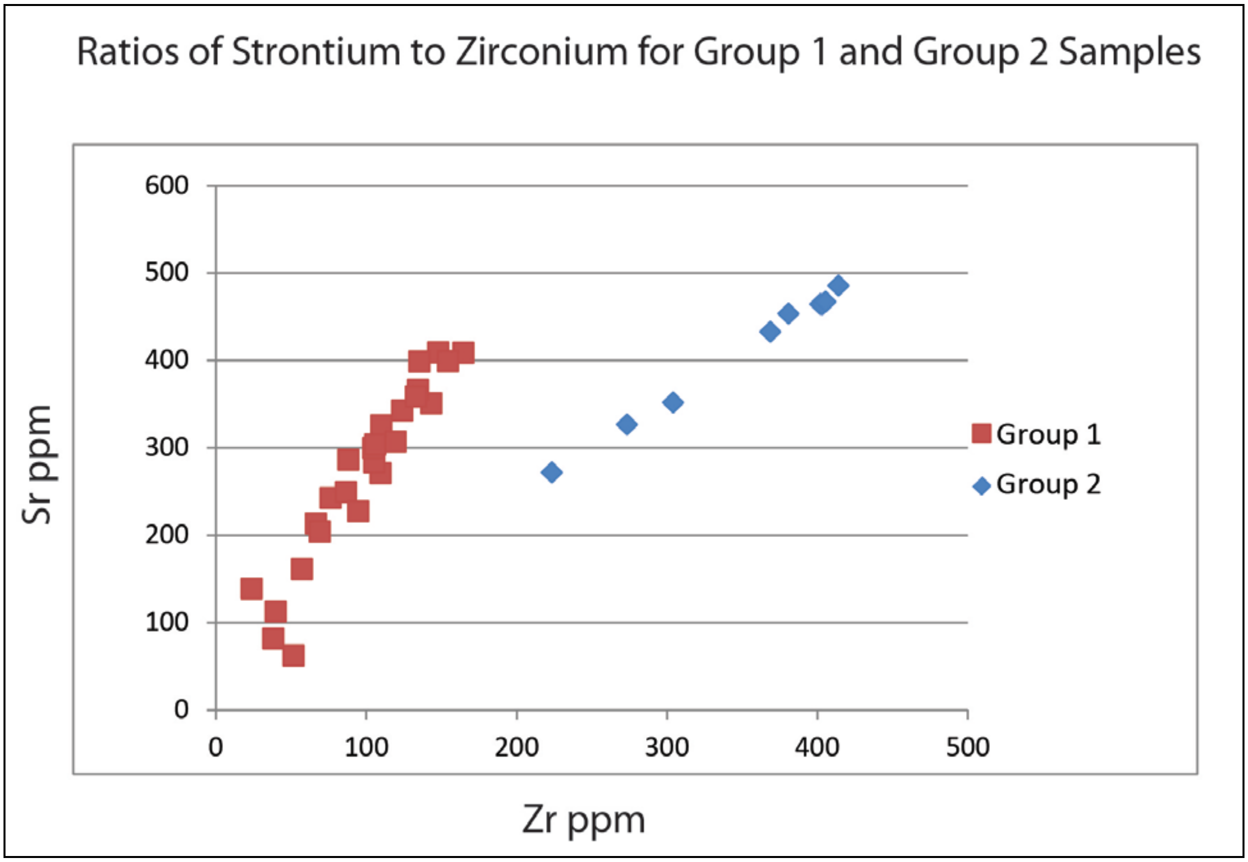

Figure 24. Graph of Strontium (Sr) vs. Zirconium (Zr) ratios of HHCTCP City Center volcanic glass samples indicating that volcanic glass from two distinct geological sources was utilized

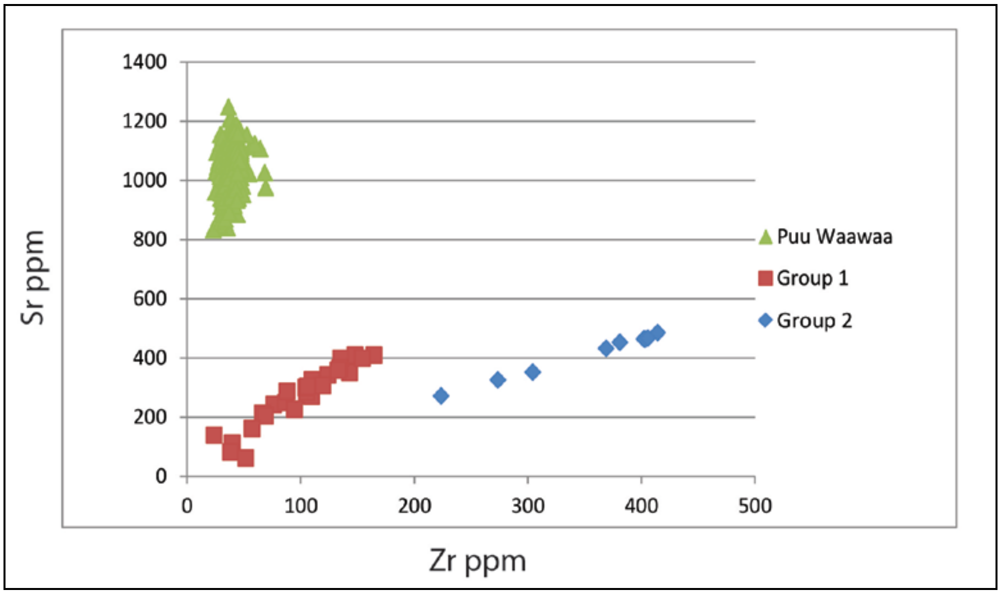

Figure 25. Graph of Strontium (Sr) vs. Zirconium (Zr) ratios of HHCTCP City Center volcanic glass samples in comparison to the quite wide-spread Pu'u Wa'awa'a volcanic glass source indicating that the HHCTCP volcanic glass did not come from that geological source

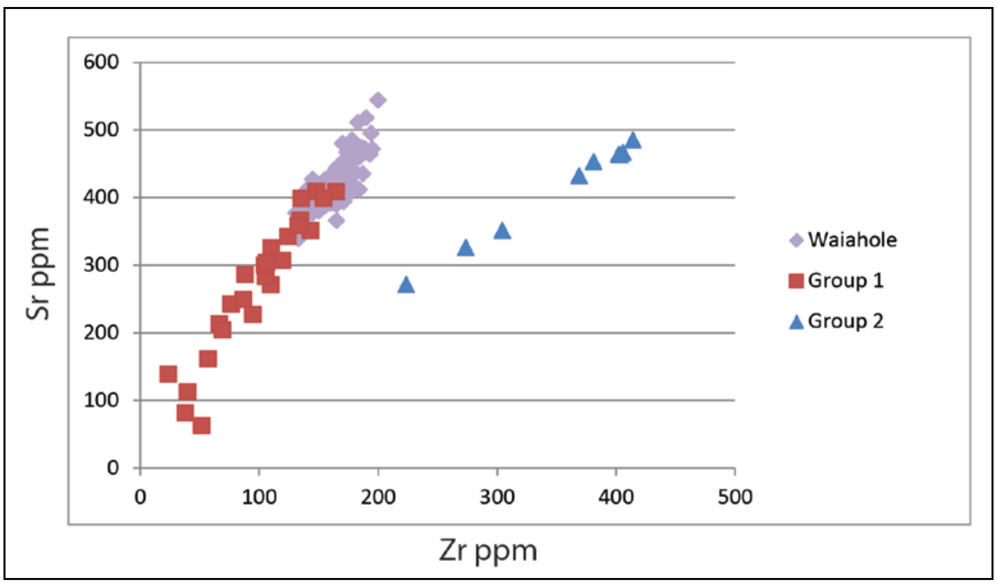

Figure 26. Graph of Strontium (Sr) vs. Zirconium (Zr) ratios of HHCTCP City Center volcanic glass samples in comparison to volcanic glass from a Waiāhole O'ahu source indicating that the "Group 1" HHCTCP volcanic glass came from a very similar geological source but that the "Group 2" volcanic glass came from a quite different geological source

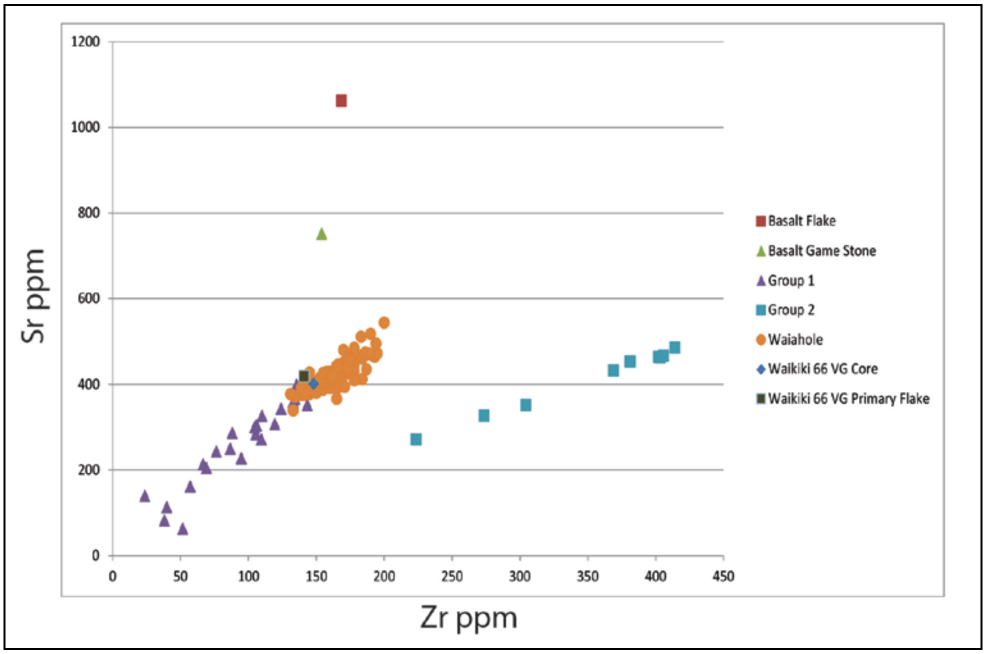

Figure 27. Graph of Strontium (Sr) vs. Zirconium (Zr) ratios of HHCTCP City Center lithic samples in comparison to other O‘ahu Island samples

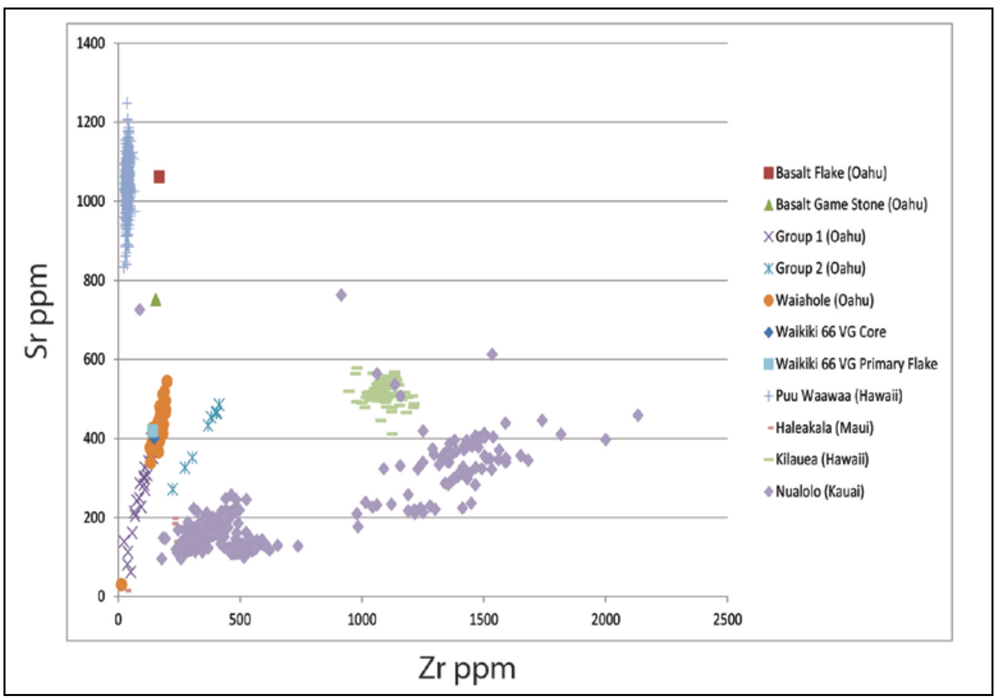

Figure 28. Graph of Strontium (Sr) vs. Zirconium (Zr) ratios of HHCTCP City Center lithic samples in comparison to other Hawaiian Island chain samples

A plot of the test excavations for volcanic glass samples (Figure 29) suggests differences in their pattern of distribution. The Group 1 (Waiāhole-lile volcanic glass is quite wide-spread with identifications from almost one end of the HHCTCP City Center Transit Alignment to the other. Cultural Surveys Hawaiʻi has previously documented this volcanic glass type in Waikīkī, and it appears to be spread further afield on Oʻahu as well (Hammatt et al. 2012:276–278).

In contrast, the identifications of Group 2 volcanic glass all occur within the 2 kilometer stretch southeast from the mouth of Nuʻuanu Stream. Two contrary hypotheses are suggested. The more limited distribution of Group 2 volcanic glass could relate to a more localized source, perhaps in the neighboring leeward, south Koʻolau volcanic range, with limited distribution. Variously, given that this immediate area may have been more likely to have been involved in interisland interchange than most areas of the archipelago, the likelihood of volcanic glass from another island might be greater in this area than in most other foci of traditional Hawaiian settlement. For example, it seems probable that the Maui and Hawaiʻi Island forces involved in the conquest of Oʻahu and the establishment of the center of Kamehameha's kingdom in what is now downtown Honolulu in the 1795 to 1810 timeframe would have transported volcanic glass from their home islands to this immediate area of Oʻahu.

The EDXRF technology offers exciting prospects to inform regarding the place of origin and patterns of distribution of lithic tools. The expansion of a data base of geochemical "fingerprints" of stone tools may well shine light on questions such as the origin and history of the Group 2 volcanic glass discussed above.

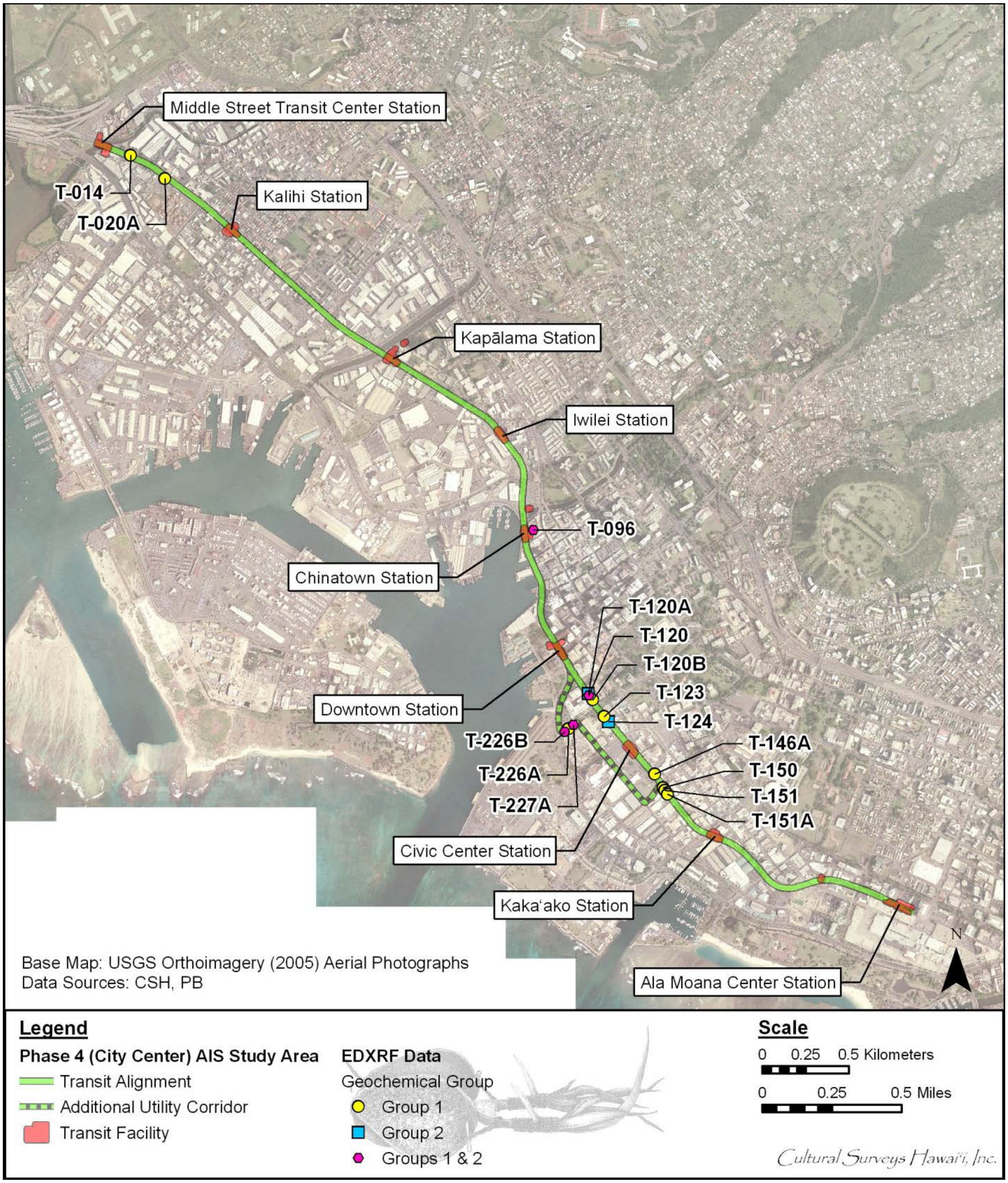

Figure 29. Distribution of the Group 1 (Waiāhole-like) and Group 2 volcanic glass (Four test excavations had both types.)